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CLASSIFICATION

GROUP

CANADIAN PATENT

LINER EXPANDER

Joe C. Stall, Tulsa, Oklahoma, U.S.A.

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FILED

PRIORITY DATE

No. OF CLAIMS

LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

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Since tools of the type mentioned above often are cmployed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential screw element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 45, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lover bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

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The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft ld.

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For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 rounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein P_c is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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- 1 1. A device for expanding a metallic liner inside a conduit which 2 device comprises a shaft element, an expanding die member attached to said 3 shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft to contact said expander member and to maintain said expander member against 9 said liner-forming member, whereby said liner-forming member is urged against 10 said liner by a substantially constant force.
- 1 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
 - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said cone member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
 2 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a sleeve-like element connected to said movable bearing plate member and slidably positioned on said shaft and a member connected to said shaft to limit the travel of said sleeve-like element.
 - 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said chaft.
 - 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

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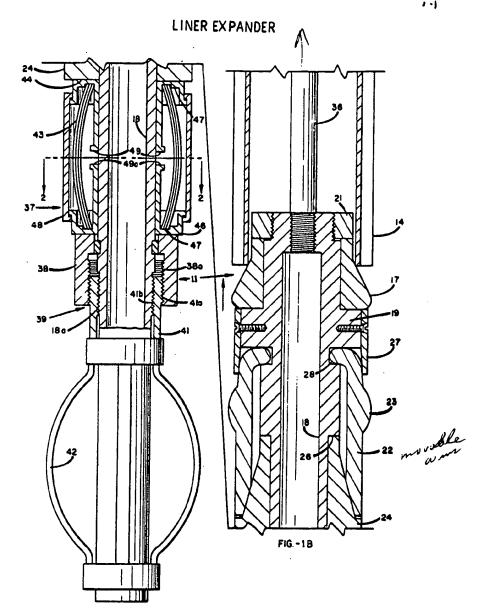
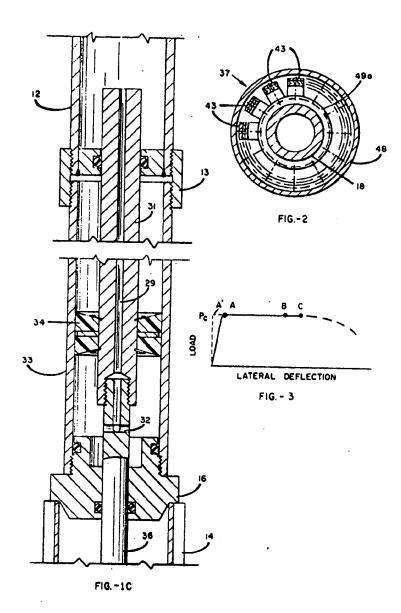


FIG.-1A



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O Her Majesty the Queen in Right of Canada, 1999

Canada http://strategis.ic.gc.ca



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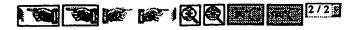
E. In a device few installing an expended metallic liner in a combit's wherein an expending the is moved through a liner positional in said stocket to expend said liner: a cylindrical shaft almost, an according die master attached to said shaft, said the newbor comprising a plurality of arm masters disposed around said shaft and being pivotable extently therefore to contest said liner, a come member alidably qualification on said shaft between said shaft and sunders to varyo said arm numbers connectly frue said shaft, and a constant force spring number positioned on said staff to contect said once number and to maintain said once number in contact with said are numbers, whereby said age tembers are urged outwardly by a substantially commutant force.

3. Die ferdoe of Claim 2 shareds said somether furce spring conters comprises a plumility of columns fixposed around said shaft, a fixer bearing plate surface and a second bearing plate scales, canh of said bearing plate members contending opposite cats of said columns, at least one of said bearing plate members being sovehily resistened on said staft and being in content with said come number, stop worse connected to said staft to limit the axial triveal of said southle bearing plate number along said staft, and compression to said southle bearing plate number along said staft, and compression to said staff, and compression to said southle bearing a triveal deflection to said staff.

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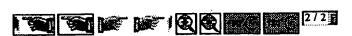
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- 5. The device of Chain 3 wherein said stop means comprises a shere-like element commented to said sovehite bearing place member and stimular positioned on said short and a sandar communied to said shaft to limit the toward of said short-like element.
- 6. The device of Chain 3 whereis sold columns have a mechangular cross-mostles, the width being greater than the thickness, and besing the wider face moved to the discrete of sale shaft.
- 7. A device for installing on expended estallis liner in a comiumis which comprises a sylindrical shaft classiful on ampending dic newtor counted on said shall, said the senter comprising a planelity of are someone disposed direnthreshielly around the outside of eald shaft and being pluotable metmaily therefrom to soutset the liner; a scalest expending maker slidsbly positioned on said shaft between said shaft and maid are explain to tops said re cetterally from suid abalts a plurelity of alander columns, cash bawing a long reutangular onces-scotion and disposed sireacterentially shout said chaft; an upper bearing plate sembar and a lower tearing plate suffer, Making positioned on said staft and conducting opposite ondo of said training sleaves whiched to each of shift bearing plate members and alidably positioned so said statt; a aboulder number on such shaff; a stiling look to stif enimme; will shoulder being supposed with the limiting sleave commuted to eath laster bearing plate mester, whereby the arial travel of said bearing plate members in limited; said column weekers breassitting their buckling look to exid any numbers to urgs said any modern estimately with a substantially constant force.

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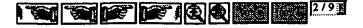
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This invention calabase to a constant force spring derice, and sore particularly, to a device for aspending a establic lines wherein an expanding due is organ against the lines by a constant force agring device.

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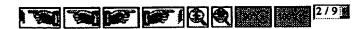
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In accordance with the present invention there is provided a conetest force spring dryine which comprises a body number, on alongsted column almost adjacent said body number, bearing plate numbers contecting the two souls of said column at least one of said bearing plate numbers to lingito timinally savelle in respect of the other and stop means on said body mimber to limit the deflection of said solven number to proving parameter deformating of said solumn element upon the application of a acopressive load thereto. In one achedinant of the invention, the foregreen essentit force spring device is explayed in a tool for expending a availic liner inside a minduit, mill constant force spring dryice being perithioned on said tool to urge as acquaining the scalar against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the economycaying drawings wherein:

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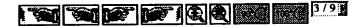


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Figure 2 to a southeast when any the apparatus of Figure 1A taken at

Figure) is a typical plot of applied Lock versus believion for the constent force spring device of the Lawrentian.

Referring to the drawings, Figure 14 is the lotton portion of a liner expending tool for one in installing a motalile liner to a well, while Figure 18 Libertrates Wer middle section of sends a tool and Figure 10 repremeats the upper section of the tool. The expending tool il is ablashed to standard well tabing 18 by compling 15 and, typically, may be lowered from the sorrises through a well easing (not shown) to a point in the swring at which it is easired to install a metallic liner. Defore inserting the test into the well, an alongsted vertically corregated liner 18 fabricated from mild stead, or other suitable miliable material, to placed on the tool. The corrupted liner is secured in position by contact at its upper end with a cylindrical shoulder number 16 and, at the lower and by content with a first-stage expansiing die 17 in the form of a transmissi circular come stdab serves as a firstnding die in the server bereinefter described. The expending die is fixedly attached to a centrally located, elongated originarical hollow shaft lô which forms a portion of the body of the tool. As shows, the expending sie 17 20 is hald in place between a lower shoulder 19 and coller 21 threaded onto the short. A plurality or morphia seem 89, presembly provided with uniteredly sularged portions 85 sear the top, are disposed in the form of a sylindar around shaft 18. The enlarged purbloss of the area 23 upon being moved outvarily emptor the liner to perform the final step of expending the convented limer into a substantially sylindrical shape. The are seahers HE are pivotally of to the sheft so as to be movehly outwardly from the sheft by a tapared expending member 26 slikebly positioned on the short to serve as a second-stage expender. The excises of the master th, as shown, moves specially along the shaft to sugage with the arms and more than outwarfily. Advantageously, the 30 incide surfaces of the area 62 and the outside surface of expanding member 25 fore sating sentions, typically cotegonal is shape. The expension of the arm members is controlled by the position of the member 20 raich moves upwardly





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until it contacts obstact 26 provided on the chaft. As member 24 moves in a documently direction area 22 feld invertily toward the shaft. The expending area 22 are held to place on the shaft by collect 27 and curratar grooms 20 recorded on the shaft.

The expending tool, comprising the fivet-stage die and the sentenstage die to drown through the liner to expend it to place in the content. Du first-stage die provides a gross disformation of the liner so that it is expended outworthy against the well of the sening. The second-stage die then passes through the liner and performs the final expension to smooth the inner surface of the liner and to provide more even content brisess too liner and the well of the caring and effect a finid-tight soal.

In operation, the liner setting tool is assembled at the surface, so described above, and a glass cloth saturated with a restance material may be exampled around the corrugated late to form the liner. The assembly is lovered the well at the location at which the liner is to be set. A signif, such so oil, is then people under presence down the wall inhing and flows through agreey 29 provided is polished roi 51, through purts 52 and into splindar 35 competed to the upper end or the aboulder 16. Upon the application of field pressure to the cylinder, the piston 34 secured to polished red 31 moves upwordly in cylinder 35. As shows, rot 36 cornects polished rot 31 and sheft sted the first-stage expending die 17. Then the piston H neves upwardly through the splinder 35 the expending die 17 und the secondstage die 22 are draus upwartly into the corrugated liner 18 and "iron out" the corregations is the liner, so that the expected liner may combon the therite wall of the casing in which it is being installed. Positioned to the shell below the expending member th is a constant torce spring member 37 which is employed to muye the expending number against the exploding steps 22 with a substantially sometant force. The force exacted against the are secular baing substantially constant, the force transmitted through the arm members to the 30 liner and to the during will be substantially accordant so that either sticking of the tool is the casing or repture of the caring is precluded. Or course, the three provided by the spring meter is preselected so that the frintional



and the many consistency with the present and the second of the second o

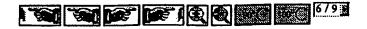


forces between the tool and the liner and the presence emrical against the oneing are estimated at predatared and safe levels. The nonriset force spring maker ensures that the context presence between the liner forming portion 25 of the sum: 22 is great cough to provide the Sorized deformation of the obsing, while preventing damage to the easing or to the tool.

The constant force spring master 77 is alide-by nounted on the shall be seed hald between the expending alasant 50 and a sylindrical lower checker number 35 forcing a portion of a differential serve alasant 39 which betweents the localing on syring number 77 to theft muster 15. The differential serve alasant comprises shaft number 15 as the certain of which are one sets threads like, the lower shallow number 30 provided with female threads 35, and thinkle number b) provided with female threads 35, and thinkle number b) provided with female threads 35, and thinkle number b) provided with female threads and the lands, respectively, to suggest with threads and shall on the certains and the lands, respectively, to suggest with threads on the shaft off the shoulder. The two sets of threads are source, such as square, modified square, or Acon threads, to vithertand very high loads and differ in pitch so that shoulder 35 is seven upwardly on the shart 15 when the shaft is revolved relative to thinkle \$1.

The shoulder 36 is secured to the shaft by splines \$5 so that it can alide longitudically, but it is not free to retain on the shaft. Finally attached to the lower set of the thinkle is a friction mater, such as two aprings \$2, a hydrallically setunded friction pat, or other resh device for frictionally sequence with the tentes with respect to the shaft. Preferably, the direction of the chonical threads \$5, e.g. right-hand threads \$5, is the same as that of the chaft threads \$5, e.g. right-hand threads \$5, is the pitch, or lead, of streeds 15a is slightly greater than therefore such as pitch, or lead, of streeds 15a is slightly greater than shoulder severing alasment \$7 to cause builting. For example, one writefactory differential screen was said up using five and one-half threads/inch square quarters threads/inch square threads on a short approximately 1.7-inch outside dissector and five and invented quarters threads/inch square threads on a short approximately 1.7-inch outside dissector and five and inventer thread





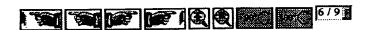
Constant force spring element 37 comprises unlies element \$5, siventageonally convinting of a plurality of elongried column displaced around short

18. Upper bearing plate number \$6 in to contact with the apper ends of the
actume and is elifably positioned on shart 18 to trements the force of the
spring longitudinally against the bottom and of expendes senter \$6. Lower
bearing plate member \$6 contacts the lover sents of the columns and is moved
tymerally along the shart by lengthedizal movement of local smoother \$8 on a
result of revolving differential movement \$9. Grooves \$7 are provided
in sents of the bearing plates, to form an upper race and a lover race, into
which the costs of the columns are inserted. These grooves may be shaped to
conform with the shape of the column such if sactivel. A cover \$8 may be
employed to exclude foreign mitter from the spring mechanics and to protect

A seems for limiting the defination of the columns to required. Although the column element functions in a backled condition, application of . erossalve sompressive load thereto would enume total failure or repture of the is. Therefore, a pair of stope by each to are provided for this purpose. en, the stope are rigidly connected to the bearing plates, and, in effort comprise upper and lower limiting slacres positioned on the shaft to alide longitudinally therem. The ends of the stops may move toward, or many from, each other so the look in the spring number vertes. Lover slaves bys isted from moding down by laster aboulder 36 nomeoted to the shart 18. T, the spacing between the ands to much as to limit the longitudinal transl of the bearing plate members on they more together to prevent perman deformation of the column almost \$3. Warrows alternative manus for preventing stanage to the column element may also be employed. For example, pink or rings someted on the chaft say serve as stope, or the cover 48 provided with suitable communices may be suplayed for this purpose to limit longitudinal and/or lateral seffection of columns.

The columns of the column element 45 may be arranged eround the spart 16, which as shown here force a portion of the body of the spring flavor, with made of the columns fitted in the reces 57. The solumns may be

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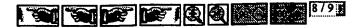




ritied closely tognihur as shows, or way he spared around the race, with separators used between them to maisteds the desired sparing. The rember of construction. For example, the elements ratio of the column may be varied withly, set the column may be reach, flat, firmt or hanged. The preferred construction is a thin, element column with nomined ands, free to now within the races shaped to the coveniers of the column cole. Materials which may be estimated to the support of the column and he alloy steels, chronius and michal-shronius stainless steels, various appear been allique, such as penspher bronze, beryllius sopper, the high sickel alloys see other similar materials providing satisfactory symbosical properties. Typically, the individual column are of long rectangular cross-cention, with the width being greater than the thickness, and arranged so that the wider face of the unimum is somewhat to the simular of the about. Thus, with surfacions consensation loading, the columns bookle, and tend shout the said having the loast consent of inertia, e.g., outerally may frue the shaft 18.

For example, a group of columns 0.167-inch thick by 0.438-inch wife by 10.626-inches long, with the ands rouwish, were febrioated from L.C.S.I \$360 steel, quenched and drawn at 575°F. Buth column was found to require a 20 critical suspension loading of MSO pounds in order to bankle the adduct. . After builling, the selmes were fruit to have a very flat spring characteris-Mr. as shown in Figure 3, wherein Po is the critical backing load and point ste the load and deflection at which the street is the extreme fibers m unesed the yield point of the untertal. Theoretically, the shape of this spring characteristic ourse is described by entre CA'ABC. Actually, this curve is described by CANG due to friction in the system. Points & and 8 represent typical straing limits, which, of course, may be waried as the appliantion for which the spring is designed. For example, where a le number of Chemiag spoise are not empiriculated, a working stress just below the 30 Field point may be used, while with a great number of flexures, the working or be held to less than the enformes limit of the setterial of a tion. In the above-munificed tests, the lateral marketion was limited to

7/9



approximately one inch, at which the longitudinal defloration was approximately 0.225 inches. From more deflection to the sections deflection, the \$50-pound loading was found to be substantially constant.

In emother test a spring device was built, as down, employing 80 columns, each having a critical buckling load of 1250 possès. The interal definition was limited between 0 and about 1.00 inches by emprogratically positioning the stope. Open compressional loading, the spring element buckled at echaruntically 25,000 possés and from a longitudinal definition of 0.0k instead (buskling) to should 0.15 inches the load remained substantially at 25,000

Of course, in conjusting a spring element as above it in advantagements obtain the greatest possible value of longitudinal definations for specified values of laboral deflection and artical bushling load, while unintending the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 13 and 2, with multiple flat unstare units or seath columns.

In the operation of the shows expending tool for setting a liner in well excised, the mede-up tool is lovered into the well as sectional above, with the area 22 in the retreated position. Then the tool is at the desired level, the well tidding is revolved. The friction number of tangens with the wall of the saxing and necessary thinkin by true revolving. With several revolvings of the tables, lower shoulder 35 is moved apossedly by differential server 39 to bush to oping almost 37 which has a predefending writtent bushing level. This level is transmitted severally against the lower and of expender 36, and the tapered surface is engaged with the tapered surface on the lastes of the orne at to args the large outstary with a substantially constant furce proportional to the critical bushing load of the spring element. Extranguarity, the expending tool is passed through the liner to expend it in the casing in the meaner described hereighe fore.

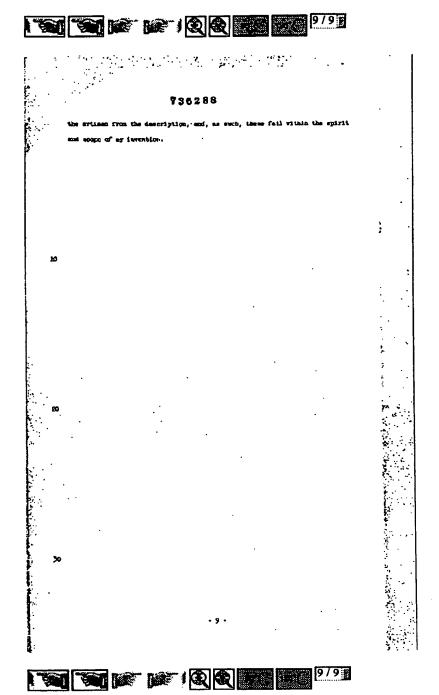
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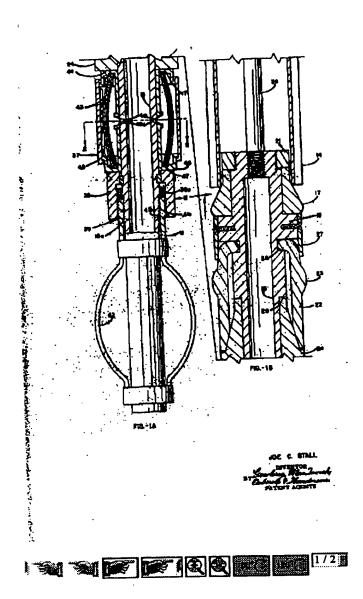
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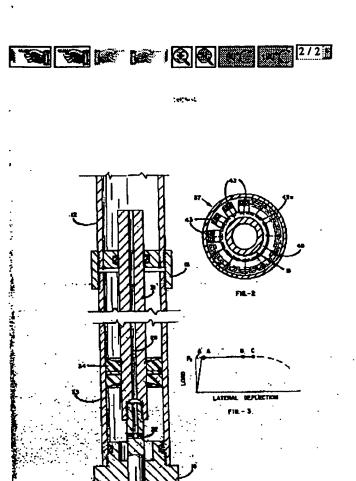






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